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Anticipating Causes and Consequences

Alan Garnham, Scarlett Child, Sam Hutton

University of Sussex

Author Note

Correspondence should be addressed to: Alan Garnham, School of Psychology, Pevensey 1 Building, University of Sussex, Brighton BN1 9QH, UK. E-mail: A.Garnham@sussex.ac.uk.

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Abstract

Two visual world eye-tracking experiments investigated anticipatory looks to implicit causes and implicit consequences in two clause sentences with mental state verbs (Stimulus-Experiencer and Experiencer-Stimulus) in the first main clause, and an explicit cause or consequence in the second. The first experiment showed that, just as when all continuations are causes, people look early at the implicit cause, when all continuations are consequences they look early at the implicit consequence, for the same verbs. When causes and consequences are intermixed, people direct their looks at the cause or consequence on a trial-by-trial basis depending of the connective (“because” or “and so”). Numerically, causes were favored overall, even when all the endings were consequences, but the effect was only significant at the end of the sentences in Experiment 2. The results are discussed in terms of rapid deployment of causal and consequential information implicit in mental state verbs, and in relation to conflicting accounts of why causes or consequences might generally be favored.

Keywords: anticipation; implicit cause; implicit consequence

Highlights:

- Listeners look early at (pictures of) implicit consequences, as they do with implicit causes.
- When implicit causes and consequences are mixed, looks change on a trial-by-trial basis.
- Numerically, very early looks tend to favor causes, not consequences, but this effect requires further investigation.

Introduction

Inference has long been a central topic in psycholinguistics (see, O'Brien, Cook, and Lorch, 2015, for a recent overview), and implicit causality is one phenomenon that has been extensively studied in relation to inference making (see, Garnham, 2001, Chapter 9 for a review of work to that date). Implicit causality is a property of interpersonal verbs (see, e.g., Hartshorne, 2014; Hartshorne, O'Donnell, & Tenenbaum, 2015, for recent evidence in favor of this view). When an eventuality (event or state) is described using such a verb, the cause of the eventuality appears to rest (or most likely rest) with one or other of the protagonists. For some verbs, such as "charm" and "annoy", it is with the grammatical subject of a simple active declarative sentence and with other verbs, such as "respect" and "dread", it is with the object. As Garnham (2001: 122) points out, implicit causality can be used in the process of establishing coherence relations between sentences and clauses, and in doing so can resolve indeterminacy in the reference of pronouns and other anaphors. More specifically, in (1)

(1) John charmed Bill because he had an engaging manner.

"because" signals one of a small number of relations between the eventualities in the two clauses (Effect-Cause being one of them), and general knowledge suggests that someone with an engaging manner is likely to charm rather than be charmed. So, in (1) everything fits together to suggest that it was John rather than Bill who had an engaging manner. In this example, the explicit cause is congruent with the implicit cause and, as many experiments have shown (see Garnham, 2001), processing is expedited in this case compared to cases in which implicit and explicit causes do not match, as in (2)

(2) John charmed Bill because he was susceptible to flattery.

From the point of view of inference making, the inference in (1) is that the person with the engaging manner is John ("he" = John, for short). In (2), the inference is that the person susceptible to flattery is Bill, the person being charmed ("he" = Bill). Implicit causality helps

the inference in one case, but goes against it in the other. World knowledge wins out against implicit causality, but implicit causality affects processing. By the end of the sentence, the correct interpretation is (almost always) computed, with the effects of verb semantics and coherence, sometimes signaled by the conjunction, taken into account. Any theory of text comprehension must explain these facts. However, these end-of-sentence effects do not determine when the various sources of information have their effects on processing, a question that has come to the fore in the recent literature on implicit causality, as discussed below.

In characterizing these inferences, we are taking account of the information in both clauses of the sentence. From the point of view of processing, this observation might suggest that the inferences are, or might best be, computed in a backwards direction, once the basic information about the eventualities in the two clauses has been established. Indeed, a major debate in the inference literature has been about whether inferences are made in a forwards or backwards direction, or, more generally about which inferences are made in which direction, and under what circumstances.

One view is that inferences are only made in a backwards direction, at the point in a text where they are need to establish coherence (Corbett & Doshier, 1978; Doshier & Corbett, 1982; Singer, 1980; Thorndyke, 1976). On this view there is a clear rationale for why the inferences are made – without them a coherent interpretation of the text cannot be established. And, as the implicit causality examples above indicate, it is relatively easy to characterize the content of inferences made in a backwards direction. Other accounts suggest that forward inferences, although sometimes made, are severely restricted. McKoon and Ratcliff's (1992) Minimalist Hypothesis proposed that only inferences that are based on readily available information or that contribute to local coherence are made in a forward direction. Garnham (e.g., 2005) suggested that inferences based on the occurrence of single

words might be made in a forward direction. As well as inferences based on gender stereotypes and reference into anaphoric islands, implicit causality information is generally thought to be associated with the occurrence of single verbs (see, e.g., the original discussion by Garvey & Caramazza, 1974, and the work by Hartshorne and colleagues, mentioned above), and so might be made in a forward direction.

Despite this possibility, on the basis of empirical data from probe word experiments, Garnham, Traxler, Oakhill, & Gernsbacher (1996) concluded in favor of the Integration Account of the use of implicit causality information, which is a backwards inferencing account. In sentences such as (1) and (2) the congruity effects of implicit causality were only apparent at the end of the second clause, when information from the two clauses can be integrated. This account was also supported by data from the eye-tracking-while-reading paradigm (Stewart, Pickering, & Sanford, 2000). The only set of results prior to the visual world studies discussed below that suggested earlier use of implicit causality information (McDonald & MacWhinney, 1995) was susceptible to a strategic, task-based, explanation (McDonald, 1997), with no early effects in experiments where strategic prediction was not possible.

In any case, the notion of forward inference is beset with two, interrelated, problems. The first, pointed out many times in the literature favoring only backwards inference making, is that, at any point in a text, many inferences are possible, perhaps indefinitely many, depending on how the inferences are characterized. Any particular inference is unlikely to be relevant to how the text actually develops. The other issue is that, without a final product of inference making – a coherent interpretation of a text, it can be difficult to characterize the content of an inference. Consider the case of implicit causality. The inference in (1) is something like “It was John who had an engaging manner”. That inference cannot, with any justification, be made simply when the verb “charmed” is encountered. So, we appear to be

left with a vaguer notion, such as “Something about John, or something John did, is (likely) what charmed Bill” or, even: John is likely to be mentioned in the upcoming text, because he is the likely cause of the charming, and causes tend to be rementioned.

It is perhaps for this reason that some researchers have turned to the notion of prediction, rather than forwards inference, in text comprehension, sometimes formalized in the framework of linear predictive coding as applied to brain functioning (e.g., Friston, 2009). A prediction can be about any aspect of anticipated upcoming content, not necessarily an inference to a proposition or set of propositions.

Returning to implicit causality, and to the question of when implicit causality information is used in processing, Garnham et al. (1996) contrasted the Integration Account with Focusing Accounts on which an implicit cause is immediately focused, for example when the verb “charmed” in (1) is processed, and hence implicit causality information has an effect before the point of information integration. Upcoming content that can be related to the focused (implicit) cause is then easier to process than content that is difficult to relate to that cause. Similarly, ambiguous content, such as a referentially indeterminate pronoun, might be more easily related to the implicit cause than to the other protagonist.

In our previous discussion we characterized implicit causality as supporting or failing to support a coherence creating inference about which protagonist a pronoun refers to. A Focusing Account suggests that a referentially indeterminate pronoun would be considered, in the first instance, to refer to the implicit cause, even before disambiguating information (for example, at the end of the “because” clause in (1) or (2)) has been encountered. However, as this description makes clear, focusing is not, of itself, inference making.

Despite the failure of Garnham et al. (1996), Stewart et al. (2000) and McDonald (1997 – where strategic processing was not possible) to find evidence for Early (focusing) effects of implicit causality, more recent, visual world eye-tracking, studies (Cozijn,

Commandeur, Vonk, &, Noordman 2011; Itzhak & Baum, 2015; Järvikivi, van Gompel, & Hyönä, 2017; Pykkönen & Järvikivi, 2010; van den Hoven & Ferstl, 2019), have shown that implicit causality information has an influence on processing earlier than the Integration Account suggests. In these studies, participants look preferentially at the picture of the implicit cause (compared to the other protagonist) while and immediately after they hear “because”, and before any (other) disambiguating information has been encountered. In addition, Pykkönen and Järvikivi (2010) reported even earlier preferential looking, before the (Finnish equivalent of) “because”.

Preferential looks to the implicit cause do not mean that an inference has been made, for example, the inference that Bill did something to cause the charming event, or even that “he” = Bill. They certainly do not mean that a specific cause has been inferred. And they do not determine the final interpretation of the sentence. They do however, indicate the early availability and use of implicit causality information. One possible interpretation is that a prediction has been made about the cause, or the probable cause, and that a continuation of the sentence in line with that prediction is easier to process than one that is not in line with the prediction. However, for our purposes, it is not crucial whether the focusing effect of implicit causality is best characterized as forward inferencing, prediction (possibly conceptualized as the use of Bayesian priors, Norris, McQueen, & Cutler, 2016), anticipation (Kuperberg & Jaeger, 2016), preparedness (Ferreira & Chantavarin, 2018), or as expediting later backwards fit with context (Norris, 1986). The crucial point is that implicit causality information is used before the point where full integration is possible.

Whatever the correct characterization, a complication arises, which illustrates the more general problem of identifying the relevant properties of discourse context that affect the processing of upcoming information. In addition to implicit causality, interpersonal verbs also possess the property of implicit consequentiality (Stewart, Pickering, & Sanford, 1998;

see also Au, 1986), although it has been less extensively studied than implicit causality. Furthermore, Crinean and Garnham (2006) pointed out that the norming data collected by Stewart et al. showed that, for three of the four main classes of interpersonal verbs recognized by Au (1986), namely SE, ES, and AP (Stimulus-Experiencer; Experiencer-Stimulus; Agent-Patient), the implicit cause and the implicit consequence¹ are different, and these differences relate to the thematic roles associated with the verbs, which name the verb classes. For the fourth class (AE, Agent-Evocator verbs) implicit cause and implicit consequence are the same (the Evocator). So, corresponding to (1) “John charmed Bill because he had an engaging manner”, in which the explicit and implicit causes match, in “John charmed Bill and so he was keen to continue the friendship” the implicit and explicit consequences match (“charm” is an SE verb, for which the implicit consequence is the Experiencer, Bill in this example). We note, again, that when these sentences end, they are (almost always) given the correct interpretation. Our question is when properties such as implicit causality and implicit consequentiality are used in comprehension and how they interact with the presence of connectives such as “because” and “and so”. The fact that two biases, with opposing tendencies, can be associated with the same statement (e.g., “John charmed Bill”) makes the question of particular interest, as we know from previous literature that both biases can affect both processing and final interpretation.

In relation to Focusing, and on-line processing more generally, it is, therefore, unclear whether implicit causes should be focused, or implicit consequences, both, or neither. We will consider a number of hypotheses in this paper. First, because both causes and consequences can be taken up in the following text, one possibility is that there is No Differential Focus on causes or consequences. Related to this idea is the possibility that causal effects in previous studies arise because all the sentences are about causes, and so the effects may reverse when all the sentences are about consequences (Strategic Focus). Second,

in line with the original focusing account of implicit causality, formulated before the notion of implicit consequentiality was widely discussed, the Causal Focus theory claims that causes are focused over consequences. This temporal priority (in the history of psycholinguistic research) argument for Causal Focus is a weak one. Indeed, it is a non sequitur. However, other evidence potentially favors this theory. Children acquire “because” before “and so” (Bloom, et al., 1980), and this observation has informed theorizing on the processing of connectives by both children and adults (Sanders, Spooren, & Noordman, 1992; Spooren & Saunders, 2008). Additionally, Kehler et al. (2008, Experiment 3) provided empirical evidence that, for some types of verb with strong implicit causality biases, and in particular the mental state verbs used in the current studies, causes are highly favored in studies in which participants write continuations from sentence fragments such as “Tom disappointed Courtney” (over 50% of completions). Note, however, that sentence completions reflect final interpretations, and not on-line processing.

Against the Causal Focus theory, general considerations about the development of narratives, a plausible location for the kinds of sentences used in studies of implicit causality and consequentiality, suggest a Consequential Focus theory. In particular, Moens and Steedman (1988) argued that, in narrative, there is a natural progression from an event to its consequences, suggesting that implicit consequences might be focused over implicit causes as they are more likely to be referred to again in the upcoming text. Both events and states can have consequences, so there are good reasons for considering a general Consequential Focus theory. However, in their own more detailed theoretical development, Moens and Steedman limit their claims to verbs describing events, because, they argue, only events have a semantic structure that shows how a focus on consequences might occur. Many interpersonal verbs with implicit causality biases, and in particular mental state verbs, are state verbs. Therefore, a Restricted Consequential Focus theory is compatible with a causal

preference for mental state verbs, but a consequential focus for verbs denoting events.

Stevenson, Crawley, and Kleinman (1994) present empirical support for Moens and Steedman's proposal, in relation to both events and states.

Returning again to on-line processing, if a cause is expected following the presentation of an interpersonal eventuality, then preferential looks to the implicit cause should be apparent in the visual world paradigm, even when a consequence is actually presented, and vice versa. Such effects, if they occurred, might be found "Very Early" before any connective ("and so" signaling a consequence, or "because" signaling a cause) is encountered. Pyykkönen and Järvikivi (2010) reported Very Early Effects (before the connective) favoring causes in Finnish, though for sentences that always ended with causes. They also found an effect after the connective, but the design of the study did not allow any conclusion about a specific role for the connective (as opposed to just hearing more of the sentence). Cozijn et al. (2011) did not find evidence for Very Early Effects, only Early Effects, after the connective but before the disambiguating content. More recent studies either did not look for Very Early Effects (Järvikivi, van Gompel, & Hyönä, 2017), or did not find them (Itzhak & Baum, 2015; van den Hoven & Ferstl, 2019). Thus, the evidence for Very Early Effects is sparse, and cannot be regarded as definitive.

We have, therefore, empirical evidence, from Cozijn et al. (2011) and Pyykkönen and Järvikivi (2010), for Early (at "because"), and less convincingly Very Early (before "because" in the Pyykkönen and Järvikivi study only), effects of implicit causality. These results support the idea that the implicit cause is focused. However, other considerations give reasons to think consequences might be focused, and even that, at least in narrative texts, consequences should be focused in preference to causes. Furthermore, a recent study by Grüter, Takeda, Rohde, & Schafer (2018) provided empirical evidence for Early, and indeed Very Early, looks to consequences, for transfer verbs in the case where there is no connective

(e.g. “Donald brought Melissa a fancy drink. He/She obviously liked hosting parties.”), which disappeared when “brought” was replaced by “was bringing”. Transfer verbs are event verbs, but the imperfective aspect of “was bringing” indicates the lack of an endpoint for the event, and it is to the endpoint that the consequences would attach according to Moens and Steedman (1998). Grüter et al.’s results are, therefore, consistent with Moens and Steedman’s analysis.

The studies in the present paper start from the observation that implicit causality information, with its well-established effects on final interpretation, can be used early in on-line processing, rather than at the point of integration of information about the implicit cause and the explicit cause. More specifically, the studies address two issues. The first is whether implicit consequentiality information, which also has established effects on final interpretation, can have similar Early or even Very Early Effects to implicit causality. If so, the results of previous studies on implicit causality may depend on the materials used – sentences that always end by presenting an explicit cause (Strategic Focus). Our studies are of particular interest because the same verb has both an implicit causality bias and an implicit consequentiality bias, and these biases pull in opposite directions. The second question is whether causal information is prioritized, even when explicit causes are not, or are not always, presented (the Causal Focus hypothesis), or, alternatively, whether consequential information is prioritized, because of the typical structure of narrative (the Consequential Focus hypothesis, or a version thereof restricted to events – Restricted Consequential Focus). These theories make different predictions for on-line processing as measured in the visual world paradigm.

Except for the recent Grüter et al. (2018) study, the visual world studies reported to date have all investigated implicit causality, and have not included sentences with consequence endings (Grüter et al.’s endings were not consequences, either, and their

conclusions about consequentiality maybe be partly compromised by the fact that they tested on Source-Goal verbs). In our first study, we investigate the on-line effects of implicit consequentiality for mental state verbs. Our materials derive from a set that we originally developed for studies of implicit causality. Two such studies, with different types of comprehension question (Garnham, Hutton & Ivic, 2018), produced results similar to those of Cozijn et al. (2011). In both studies we found significant preferential looks to the implicit cause at and immediately following “because”, in a region with no other cues to the referent of the pronoun (Early Effect). In addition, given the apparent lack of any Very Early Effects, we performed Bayesian analyses on the effect of verb type (VBias: NP1 vs. NP2 implicit causality bias) on looks to NP1 and NP2 pictures in the region immediate before the “because” (which contained “padding” material, not the object NP), using the method of Dienes (2014). These analyses resulted in Bayes factors of less than one third, and hence provided evidence supporting the idea that there were no Very Early looks to the implicit cause.

In the second study presented in this paper, which again focused on on-line processing, we pseudo-randomly intermixed sentences with causal and consequential endings, so that preferential looks could not be based on the fact that all endings were causal (or all consequential).

If the Causal Focus hypothesis is true for the kind of verbs we tested, then early preferential looks to the consequence may not be found in study one, as preferential looks to the cause may dominate, at that point. However, if the pattern for consequences in the first study mirrors that for causes in previous research, that result will suggest that implicit causes and implicit consequences can behave in the same way, even if it reflects the fact that participants quickly find out that they are always presented with consequences (Strategic Focus). The second study will look to see if the preference for causes and consequences

varies on a trial by trial basis, and hence is not strategic in the sense just discussed. It will also look for any overall preference for causes (Causal Focus) or consequences (Consequential Focus).

Materials

Images

We developed a set of 84 visual stimuli for a larger set of experiments on implicit causality, using sentences similar to the ones used in the current studies. The sentences described interpersonal eventualities involving two anthropomorphized animals, which participants were asked to assume were always male and hence could be referred to as “he”. Each stimulus had four cartoon-like pictures, one in each of the four quarters of the screen (top left, top right, bottom left, bottom right). The pictures were one each of the two animals mentioned in the sentence, one of something referred to in the adverbial phrase that was added between the NP object of the main clause and the conjunction (“and so” or “because”), and one of an item not mentioned in the sentence. All images were selected from free uncopyrighted websites. The animals had neutral expressions, and were not carrying objects or performing any obvious action. The pictures did not contain any humans or other human-like characters. Pairings of animals with similar names, such as “ant” and “anteater” or with the same initial phoneme, such as “pelican” and “puffin, were avoided, as were phonetic similarities between the animals’ names and the verb in the same sentence, such as “spooked” and “moose”. Because of the problem of finding readily identifiable pictures of a large number of animals, each animal was used twice, once in an NP1-biased sentence and once in an NP2-biased sentence. Within the set of 80 stimuli intended as experimental items (the other four were practice items), the positions of the NP1, NP2, Adverbial and Distractor images were balanced as closely as possible, using the 24 different layouts for the four types

of picture. Example images are shown in the supplementary material at

<https://doi.org/10.25377/sussex.c.4842171.v1>.

Sentences

For the experiments reported in Garnham et al. (2018) we used a set of 32 verbs with strong implicit causality biases (16 NP1 biased and 16 NP2 biased). In other experiments with 40 NP1 and 40 NP2 verbs with varying bias strength, we failed to find a significant preferential looking effect. Each of the 32 verbs used by Garnham et al. (2018) was included in a sentence that consisted of a main clause and a subordinate clause, which were linked by the causal conjunction “because”. The main clause included two animal characters, a biasing past-tense transitive verb, taken from the list of 32 mentioned above, and a filler phrase or location (e.g. “The elephant disappointed the goat on the walk around the forest”). Following the causal conjunction, the subordinate clause began with the pronoun “he” which remained ambiguous given the instruction to treat the animal characters as male, followed by a long adverb, such as “obviously”, which was also uninformative as to the referent of the pronoun. Subsequent words were congruent with the bias of the verb and designed to disambiguate the interpretation of the pronoun in the intended direction.

Because there are not many more than 16 common verbs of each bias type with strong measured biases (Ferstl, Garnham, & Manouilidou, 2011), for the present studies we decided to use 32 verbs in our experimental items, repeating each one twice in the second experiment. Because ES and SE verbs (mental state verbs) tend to show the clearest implicit causality biases, we decided to use only these verb types. Our starting point was the set of 32 verbs used in the earlier implicit causality studies, but these verbs were selected before the Ferstl et al. (2011) norming and categorization study was carried out. We, therefore, replaced some verbs that were not categorized as ES or SE in that study with ES or SE verbs as appropriate.

The mean bias rating (percentage of congruent completions in a sentence completion task) for the 16 SE (NP1) verbs was 80% and for the 16 ES (NP2) verbs 87%.

We rewrote some of the sentences from the original studies, where necessary, but always ensuring that the same visual stimulus could be used. We also had to write a consequential continuation for each sentence, that could directly replace the causal one. As the elements of the visual stimulus that were mentioned in the sentence were all mentioned in the first clause, the same visual stimulus could be used for the causal and the consequential version of the sentence.

For Experiment 2, which required an additional 32 sentences, we selected visual stimuli from the remaining 52 from our larger set and wrote sentences appropriate for them. As previously mentioned, because of the rarity of common strongly biased verbs, and because we had not found preferential looking effects when verbs with weaker biases were included, we repeated each verb from the set of 32 used in Experiment 1, and wrote a new sentence around it, with both a causal and a consequential ending.

All sentences were read aloud by the same male native speaker of British English to minimize differences in speech prosody. They were recorded in a soundproof room onto a MacBook computer using the built-in microphone. The sets of sentences for the two studies were read in separate sessions. Audacity 2.1.0¹ for Mac OS X was then used to edit and analyze the audio sentences. Analysis involved recording onset times for the sentence itself, the NP1, NP2, and the filler phrase, the conjunction (“because” or “and so”), the end of the adverb following the pronoun (the point at which disambiguating information began) and the total sentence length. Sentences were spoken naturally and hence varied from 5076 to 7047ms in length. Audio files were imported into SR Research Experiment Builder software, which was used both to design and to implement the visual-world paradigm, and which provided precise and accurate audio playback.

Experiment 1

Experiment 1 examined the processing of sentences with consequential endings in the visual world paradigm. We investigated whether people who heard sentences that always had consequential endings showed preferential Early (at and immediately after the conjunction “and so”) or Very Early (before the conjunction) looks to the implicit consequence (Consequential Focus). In addition, we looked for any indication of looks to the implicit cause, which might be prioritized, if causes are more frequent or more salient than consequences after interpersonal verbs from the classes SE and ES (Causal Focus Hypothesis).

Method

Participants. The participants were 56 students and staff members from the University of Sussex (15 male, mean age 20.3 years, range 17-27), who received either course credits or payment for participation. Data from 15 participants were excluded from the analysis because those participants failed to answer 75% or more of the comprehension questions, one of which followed each sentence, correctly. Data from 41 participants were, therefore, included in the analyses reported below.

Materials. We used the set of 32 Stimulus-Experiencer and Experiencer-Stimulus verbs (16 NP1, SE; 16 NP2, ES) with strong biases chosen from the Ferstl et al. (2011) norms. The verbs were embedded in sentences that were recorded and paired with visual stimuli as described in the general Materials section.

Apparatus. An EyeLink 1000 Eye-tracker (SR Research, Ottawa, Canada) was used to track the eye movements of participants. From the right eye a monocular recording was obtained with a sampling rate of 1000Hz (one sample every 1ms). The standard 9-point calibration and validation procedure and drift correction were part of the preparation for the study, and spatial accuracy better than 0.5 degrees was maintained throughout the study.

Design

The design had one factor, Bias of Verb (VBias: NP1 consequentiality vs NP2 consequentiality), which varied within participants but between items. See below, under Results, for a description of the dependent variable, and of why Picture Looked At (NP1 vs NP2) was not a factor in the analysis.

Procedure

Participants read an information sheet and signed a consent form upon arrival. They sat around 50 cm from the computer screen of an Apple Macintosh computer running Windows XP. They rested their head on a chin-rest and their forehead on a forehead-rest. The eye tracker was positioned in front of and below the screen on the table. The eye-tracker was calibrated using a 9-point grid. The calibration was checked and drift corrected before each trial using a fixation point that appeared in the center of the screen. Once the drift correction was complete, and with the participant still focusing on the fixation point, the four images appeared on the screen and the audio playback began simultaneously. Because of the way the sentences were recorded, there was an average delay of 839msec before the beginning of the sentence was heard. Although the sentences were heard for various durations (5.1-7.0 seconds), the images remained on screen for 10 seconds. Participants were told to use the images to aid their understanding of the spoken sentences, and so were encouraged to look around the screen at the images. Attention and comprehension were assessed through simple two choice questions, with the two animals as possible answers, which appeared on the screen two seconds after the offset of the images. The questions related to the content of the spoken sentence and hence 32 different questions were constructed; referring to the first clause, second clause or the filler phrase. Subjects received no feedback but were required to obtain at least 75% correct responses for their data to be included in analysis. After participants had responded using the 'f' (left choice) or 'j' (right choice) keys on the

keyboard, a fixation point appeared in the center of the screen ready for the next trial. Four practice trials preceded the first experimental trial and the entire session lasted no longer than 30 minutes. Once all 36 trials, including the practice trials, were complete, participants were verbally debriefed.

Results

The data were processed using SR Research's DataViewer software (SR Research, Ottawa, Canada). Every 1 msec the computer had recorded whether the participant was looking at one of the four pictures, elsewhere on the screen, or off the screen. These data were aggregated into 20 msec bins, producing the proportion of time in each bin spent looking at each picture². We focused on the data for the NP1 and NP2 pictures. Because a participant can only be looking at one picture at a time (or elsewhere in the visual world) the proportions of looks to the two pictures are partially interdependent, violating the assumptions of linear modelling. However, using a difference score measure, in our case the difference between the proportion of looks to NP1 and the proportion of looks to NP2 in the relevant time period for each trial (e.g., McMurray, Tanenhaus, & Aslin, 2009) eliminates interdependent data points. So, although, for ease of interpretation, we retain Picture Looked At in our tables and figures, our analyses are on difference scores³.

For Very early effects (before the "and so") we looked at data from the "padding" adverbial phrase at the end of the main clause. The average length of this phrase (up to the start of the conjunction) was 1689 msec and the minimum was 1330 msec. We re-referenced timing to the beginning of the adverbial on a trial-by-trial basis and, given that an eye-movement takes around 200ms to plan and execute, we analyzed the period from 200 msec to 1500 msec after the beginning of the adverbial phrase. The corresponding figures for the ambiguous first part of the "and so" clause were: 1433 msec average length and 1040 msec minimum; with 200-1200 msec after the "and so" analyzed. Although end-of-sentence effects

were not the main focus of this study, we expected to find evidence at this point that the sentences had been interpreted correctly, reflected in looks at the picture of the referent of “he”, as the information from the two clauses of the sentence was integrated. From the “whole trial” plots in Figure 1 (see also Figure 4) it is clear that such effects lasted through the 10 sec period when the pictures remained on the screen. The latest point at which the ambiguous first part of the “and so” clause finished was 6520 msec into the 10 sec period for which the images were displayed. Allowing for the planning and execution of eye movements, we analyzed the period from 6720 msec into the trial to the end of the 10 seconds for which the images were displayed. We did not go beyond the 10 secs because the abrupt change to the visual display at that point may have caused disruption to eye movements.

Figure 1 About Here

Analysis. As described above, the dependent variable in the analyses was the difference between the proportion of looks to the NP1 picture and the proportion of looks to the NP2 picture (DPLooks) in the time frame selected. If participants looked equally at the NP1 and NP2 pictures, the expected value of the DV was 0. We could, therefore, use the test on the (fixed effect) intercept to see if there were significantly more looks to NP1 or NP2. We focused on the NP1 and NP2 pictures only, as these pictures represented the implicit causes and consequences. We fitted linear mixed effects models to each data set using version 1.1-17 of the lme4 package (Bates, Maechler, Bolker, & Walker, 2015) for R3.5.1 (R Core Team, 2017), using the default REML method of estimation for initial model fitting, and ML estimation for model comparison. We set contrasts for factors to `contr.sum` (effect coding). We used version 3.0-1 of the lmerTest package (Kutnetsova, Brockhoff, & Christensen, 2015) to estimate approximate degrees of freedom, and hence *p* values, for tests of the fixed effects, using the Satterthwaite method. The fixed effect was Bias of Verb

(VBias: NP1 vs NP2). For the mental state (SE and ES) verbs used in this study, a verb with NP1 consequentiality bias has NP2 causal bias, and vice versa. VBias varied within participants, but between materials.

There is no universally agreed procedure for selecting an appropriate LMM to fit to a data set. In this paper we follow a procedure presented by Bates, Kliegl, Vasishth, & Baayen (2015), which is designed to temper certain problems with Barr et al.'s (2013) suggestion of trying to fit a maximal model, subject to certain constraints. With the relatively small data sets typical of psycholinguistic experiments, including those presented in this paper, and manipulations that are within participants, within items, or both, maximal models may have a relatively large number of parameters to estimate, given the number of data points in the data set, and the models may have unsatisfactory properties, partly because of the unstable nature of the estimates. In addition, some variance components may be estimated to be zero or very close to zero, because of the estimation procedure used in lme4 (see Bates et al., 2015). The Bates et al.'s procedure aims to eliminate random effects that either contribute little to explaining variance or, by using Principal Component Analysis (from the RePsychLing package, Bates et al., 2015), that are not independent of other random effects that contribute more to explaining variance.

Very Early Effects. Table 1 and Figure 2 show the results for the Very Early Effect region. The fitted model was:

$DP_{looks} \sim V_{Bias} + (1 \mid \text{participant}) + (1 \mid \text{material})$

There was a highly significant effect of the Intercept, $t(46.73) = 7.70, p < .001$. Because the padding material comes directly after the NP2, there were considerably more looks to the picture of the NP2 in this region than to the picture of the NP1 (.384 vs. .186). As can be seen from Table 1, there was a numerical tendency to favor the cause over the

consequence (.385 and .208 vs .382 and .163), but this tendency was not significant in the model we fitted – main effect of Vbias, $t(30.33) = 1.17, p = .251$.

Table 1 and Figure 2 About Here

Early Effects. Table 2 and Figure 3 show the results for the Early Effect region. The fitted model was:

$DP_{looks} \sim VBias + (1 | participant) + (1 | material)$

The effect of VBias was significant, $t(25.83) = 2.99, p < .01$. As can be seen in Table 2, even before disambiguating information about the actual consequence was heard, but during and after the processing of the consequential conjunction “and so” and the following adverb, there were more looks to the picture of the implicit consequence than to pictures of the implicit cause (.297 and .329 vs. .256 and .263). Subsidiary analyses showed that there were more looks to the NP1 picture for NP1 consequentiality biased verbs, $t(14.09) = 2.04, p = .06$ (two-tailed, though a directional prediction justifies a one-tailed test) and more looks to the NP2 picture for NP2 biased verbs, $t(15.15) = 2.22, p < .05$.

Table 2 and Figure 3 About Here

Late Effects. Late Effects of implicit consequentiality (and causality) were not the focus of this study, as they are to be expected on any theory at the point where a proper understanding of the sentence has been computed. Such effects are clear from Figures 1 (for Experiment 1) and 4 (for Experiment 2), and we report a statistical analysis of these effects for completeness. See also Table 3 (and Table 6 for Experiment 2)

The fitted model was:

$DP_{looks} \sim VBias + (1 + VBias | participant) + (1 | material)$

The effect of VBias was significant ($t(36.66)=4.77, p < .001$), showing that consequences were looked at more than causes (.382 and .398 vs. .303 and .312) in this time period. Subsidiary analyses showed that there were more looks to the NP1 picture for NP1

consequentiality biased verbs, $t(19.23) = 2.88, p < .01$ and more looks to the NP2 picture for NP2 biased verbs, $t(20.27) = 3.85, p < .001$.

Table 3 About Here

Discussion

In this experiment people listened to a set of sentences with interpersonal verbs in their main clauses, always followed by an explicit consequence in a following subordinate (“and so”) clause, and the explicit consequence was always congruent with the implicit consequence of the interpersonal verb. Under these circumstances we found clear evidence of Early looks to the implicit consequences, which varied according to the bias of the verb. By Early, we mean at the conjunction “and so”, a following referentially indeterminate pronoun (“he”), and an uninformative (about the referent of the pronoun) adverb are heard. These results parallel effects reported for implicit causality by Cozijn et al. (2011) and Pyykkönen & Järvikivi (2010) and our own earlier experiments (Garnham et al., 2018), where early looks to the Implicit cause were found. As expected, these effects continued to the end of the sentence, and indeed became more pronounced (see Figure 1) as the explicit statement of the consequence, which was always congruent with the implicit consequence, was revealed. For the verbs used in this experiment, the implicit consequence and the implicit cause are different, so looks at the implicit consequence are looks away from the implicit cause.

We also looked for Very Early Effects, prior to the conjunction “and so”, before there was any explicit information that a consequence would be presented. However, since all sentences in this experiment did present explicit consequences, participants could have anticipated consequences on that basis. Nevertheless, we did not find evidence of Very Early anticipation of consequences. If anything, the numerical pattern suggested that causes were favored at this point, though the effect was not statistically significant in the model fitted by the procedure we had chosen to use a priori. The issue of the presence or absence of Very

Early Effects, and their nature, therefore, remains unresolved. Cozijn et al. failed to find evidence of such effects in experiments in which all the continuations were causal. Pyykkönen & Järvikivi (2010) did report such effects, whereas in our own studies on causation (Garnham et al., 2018) Bayesian analyses provided evidence against such effects. Our results are compatible with the Strategic Focus hypothesis, but with a hint that the Causal Focus hypothesis is worthy of further investigation.

Experiment 2

Experiment 2 examined the processing of sentences with both causal and consequential endings, pseudo-randomly intermixed, in the visual world paradigm. We investigated whether people who heard this pattern of sentences still showed preferential early looking to the cause or the consequence, or a trial by trial basis. We would expect such preferential looking at or after the conjunction (“because” or “and so”). Before that point it is not possible to know how the sentence will end. Any Very Early effect, before the conjunction, would have to reflect an overall bias towards causes (Causal Focus) or consequences (Consequential Focus). According to Kehler et al. (2008) and others, that might be to the cause. But general considerations about the progression of narratives suggests it could be the consequence.

Method

Participants. The participants were 44 students and staff members from the University of Sussex (12 male, mean age 23.1 years, range 18-45), who received either course credits or payment for participation. Data from 4 participants were excluded from the analysis because those participants failed to answer 75% or more of the comprehension questions, one of which followed each sentence, correctly. Data from 40 participants were, therefore, included in the analyses reported below.

Materials. We used the same set of 32 Stimulus-Experiencer and Experiencer-Stimulus verbs (16 NP1, SE; 16NP2, ES) with strong biases in the Ferstl et al. (2011) norms as in Experiment 1. As described in the general Methods section, each verb was used twice, and embedded in two sentences, each of which had a causal and a consequential version.

Design

The design was a 2x2 with factors Type of Subordinate Clause (Conj: causal vs. consequential) and (causal) Bias of Verb (VBias: NP1 = NP1 causality/NP2consequentiality vs. NP2 = NP2 causality/NP1 consequentiality). Both factors were varied within participants. Conj varied within items, but VBias varied between items. There were two lists of stimuli. Each verb occurred once with a causal ending in each list and once with a consequential ending. If a verb in one of its two sentences occurred with a causal ending in one list, it occurred with a consequential ending in that sentence in the other list.

Apparatus

The apparatus was the same as in Experiment 1.

Procedure

The procedure was the same as in Experiment 1, except that there were 64 experimental items, rather than 32.

Results

The data were processed using DataViewer as in Experiment 1.

Again, we examined the sound files using Audacity 2.1.0. The average length of the adverbial, where Very Early effects might be detected, was 1670 msec and the minimum was 1220 msec. We examined the data from 200 to 1400 msec after the beginning of the adverbial. The corresponding figures for the ambiguous first part of the second (“and so” or “because”) clause were: average length 1332 msec; 900 msec minimum. Data from 200-1100

msec after the beginning of the conjunction were analyzed. LMMs were fitted in the same way as in Experiment 1.

For Very Early effects, any favoring of causes or consequences would be apparent in the effect of VBias. If causes are favored, there will be more looks to NP1 for NP1 causally biased verbs, and more looks to NP2 for NP2 causally biased verbs. Because implicit causes and implicit consequences are different for these verbs the opposite pattern would indicate that consequences were favored. For this analysis we excluded the Conj factor, because, in the region of the sentence we analyzed, the conjunction had not yet been heard. The whole trial (10 sec) plot is shown in Figure 4.

For Early effects, the crucial evidence comes from the Verb Bias (VBias: NP1 vs NP2 causal bias = NP2 vs NP1 consequential bias) x Ending (Conj: “because” vs. “and so”) interaction. For NP1 causally biased verbs (NP2 consequential), there should be more looks to NP1 with causal endings and more looks to NP2 with consequential endings. The reverse pattern should be found for NP2 causally biased verbs.

Figure 4 About Here

Very Early Effects. Table 4 and Figure 5 show the results for the Very Early Effect region. Because this part of the sentence occurred before the conjunction (“because” or “and so”) had been heard, the factor Conj was omitted from this analysis.

The fitted model was:

$DPlooks \sim Vbias + (1 | participant) + (1 | item)$

As in Experiment 1, there was a highly significant effect of the fixed effect intercept ($t(44.85) = 5.72, p < .001$). Because the padding material comes directly after the NP2, there were considerably more looks to the picture of the NP2 in this region than to the picture of the NP1 (.336 vs. .231). As can be seen from Table 4, there was again numerical tendency to favor the cause over the consequence (.243 and .344 vs .220 and .328), and in this case the

tendency was marginally significant, two-tailed, $t(125.34) = 1.81, p = .0732$. The effect of Vbias on difference in proportion of looks to NP1 and NP2 was -0.085 for NP1 causally biased verbs and -0.124 for NP2 biased verbs.

Table 4 and Figure 5 About Here

Early Effects. Table 5 and Figure 6 show the results for the Early Effect region. The fitted model was:

$DPlooks \sim Vbias * Conj + (1 + Conj | participant) + (1 + Conj | material)$

The only significant effect was the critical two-way interaction of VBias and Conj, ($t(115.68) = 3.37, p < .01$). As can be seen in Table 5, even before disambiguating information about the actual consequence was heard, but during and after the processing of the conjunction “because” or “and so”, the pronoun and the following adverb, there were more looks to the picture of the implicit cause than to pictures of the implicit consequence in causal continuations, $t(61.58) = 2.38, p < .05$, $DPlooks \sim Vbias + (1 | participant) + (1 | material)$. The reverse was true for consequential continuations $t(1239.00) = 2.47, p < .05$, $DPlooks \sim Vbias + (1 | participant)$.

Table 5 and Figure 6 About Here

Late Effects. Table 6 and Figure 4 show the results for the Late Effect region. The fitted model was:

$DPlooks \sim Vbias*Conj + (1 + Vbias:Conj | participant) + (1 | material)$

For this analysis, the participant random interaction effect has to be coded as $dummy(Vbias):dummy(Conj)$, or the wrong model will be fitted.⁵ As in the analysis of the Early Effects, the two-way interaction of Vbias and Conj was significant ($t(126.47)=7.65, p < .001$), which, as can be seen from Table 6, arose from a preference for looking at cause when the conjunction was “because” (.237 and .229 vs .189 and .212) and for looking at the consequence when the conjunction was “and so” (.225 and .236 vs .215 and .192). There was

also a main effect of Vbias ($t(126.47) = 2.05, p < .05$). This effect indicates a tendency to favor causes over consequences overall (i.e., independent of conjunction .359 vs .330), as did the corresponding effect in the Very Early analysis.

Table 6 About Here

Discussion

In previous experiments (Cozijn et al, 2011; Pyykkönen & Järvikivi, 2010; Garnham et al., 2018 for causal endings; Experiment 1, above, for consequential endings) Early Looks to the cause or consequence (as appropriate) have been found. However, those findings might have reflected a general bias to look at causes (or consequences), given that participants were always hearing about causes (or consequences) – the Strategic Focus hypothesis. In this experiment, causes and consequences were interspersed in an unpredictable way, and yet participant's eye movements were still determined (on a trial-by-trial basis) by whether they were hearing about a cause or a consequence, and by the causal or consequential bias of the verb. These results provide a clear indication that both implicit causality and implicit consequentiality information can be used early in on-line processing (i.e., earlier than suggested by Integration account), and on a trial-by-trial basis.

This experiment also provided evidence that causes were favored over consequences, despite the fact that causes and consequences were equally represented – the Causal Focus hypothesis. However, this effect was only significant at the end of the sentence, where the end of the subordinate clause and its relation to the main clause were different in the causal and consequential conditions. There was some hint of a Very Early effect favoring causes, but it was not statistically significant. Given the varied evidence for Very Early effects in the literature (see above), such effects require investigating more thoroughly in more highly powered experiments.

General Discussion

In the past the argument has been made that inferences in text comprehension are best made in a backwards direction. And in several domains, including that of implicit causality, there is empirical evidence that favors this view (Garnham et al., 1996; Stewart et al., 2000). However, there is also evidence from more recent visual world experiments (e.g., Cozijn et al., 2011; Pyykkönen & Järvikivi, 2010, and others) for the on-line availability of implicit causality information at a point before a precise backwards inference can be made (favoring the Causal Focus hypothesis). This availability could take the form of a full-blown forwards inference, a prediction or anticipation of what might occur in the upcoming text, or a representation of content that allows some types of upcoming information to be integrated more easily than others. Although it is well established that biases such as implicit causality affect comprehension, a potential problem for this set of findings is that interpersonal verbs, of the kind used in studies of implicit causality, have implicit consequences as well as implicit causes (Stewart et al., 1998). Furthermore, for certain common types of “two person” interpersonal verbs, and in particular mental state verbs, such as “astonish” and “admire”, the implicit cause and implicit consequence are different (Crinean & Garnham, 2006). Both biases affect the final interpretation of a sentence, so the question arises of how and when they affect on-line processing. The potential problem of both biases being in play together might be avoided if the effect of implicit causality is found only after the occurrence of a causal connective (“because” in English), as it is in the data of Cozijn et al.. However, an earlier occurrence, as reported by Pyykkönen & Järvikivi, is less easy to accommodate, because it is not clear why causes might be favored on-line over consequences without any information about whether a cause or a consequence will materialize. The problem becomes more acute when one considers that the natural progression in a narrative is from an event to its consequences (Moens & Steedman, 1988; Stevenson et al., 1994), so that one might

expect the implicit consequence rather than the implicit cause to be mentioned in the upcoming text, where the two are different. Such a pattern of results would favor a Consequential Focus hypothesis. However, the specific proposal of Moens and Steedman limits this effect to events, not states, consistent with Restricted Consequential Focus. In any case, even if the effects of implicit causality and implicit consequentiality come into play only when just one of them is relevant (i.e., after a causal or consequential connective), and given that both are known to exert their influence by the end of the sentence, questions still remain about the time course of their effects, and whether one has an earlier or more pronounced effect than the other.

A possible reason for the focus on causes in the visual world experiments mentioned above is that all the texts presented were about causes rather than consequences (the Strategic Focus hypothesis). No experiment to date has investigated the possible early availability of implicit consequentiality information or its relation to early availability of implicit causality information when both might be relevant. Another fact that needs to be taken into consideration is the empirical evidence that some types of interpersonal verbs, and in particular the Stimulus-Experiencer and Experiencer-Stimulus verbs that are commonly used in studies of implicit causality, are preferentially followed by causes, rather than other types of continuation, including consequences. This pattern of preferences emerges, for example, in “off-line” sentence continuation studies (Kehler et al., 2008). This fact might, nevertheless, be consistent with the observations of Moens and Steedman, because their analysis applies to verbs describing events, whereas mental state verbs, as their name suggest, describe states.

Experiment 1 in the current study was a visual world experiment in which consequences alone were presented. For comparability with our previous studies of implicit causality, we continued to use mental state verbs, which do have implicit consequences, but may not have the additional bias to consequences that Moens and Steedman identify for event

verbs. In the second experiment in the current study both causes and consequences were presented, pseudo-randomly intermixed. In the first study we looked to see if consequences produce Early Effects in the same way as causes, and if so whether they produce effects only after a consequential connective (“and so”) or whether there are earlier (Very Early) effects when every sentence ends with an explicit consequence. We also considered the possibility, based on the observations of Kehler et al., that causes might be favored over consequences (in Very Early looks, and maybe even in Early looks) because of a general bias with verbs of this kind for causes to be expected, even though explicit causes never occurred in the experiment.

In the second experiment, we looked to see if causes and consequences were favored on a trial-by-trial basis. As it was not possible to predict whether the ending would contain a cause or a consequence, any trial-by-trial effect could only be expected after the causal or consequential connective (“because” or “and so”) had been heard. We did find such an effect, indicating the rapid deployment of both implicit causality and implicit consequentiality information in on-line interpretation. However, as we have already pointed out, such effects do not necessarily indicate the use of that information to make specific forward inferences.

Our primary focus in this paper was on Early Effects, in the subordinate clause, but before other disambiguating information had been encountered, because they have not previously been demonstrated for implicit consequentiality and mental state verbs. We presented Stimulus-Experiencer and Experiencer-Stimulus mental state verbs, which have different implicit causes (Stimuli) and implicit consequences (Experiencers). In Experiment 1, we showed early effects of implicit consequentiality, parallel to those that we, and others, reported for implicit causality. These effects, of both causality and consequentiality, show that such information can be deployed early in on-line processing, because the cause or consequence varied pseudo-randomly from trial to trial, depending on whether the verb was

NP1 causality biased (e.g. an SE verb, which is NP2 consequentiality biased) or NP2 causally biased (e.g. an ES verb, which is NP1 consequentiality biased). To the extent that results for implicit causality and implicit consequentiality parallel each other, they support the No Differential Focus hypothesis for causes or consequences. However, the results may depend to some extent on the fact that the sentences are always (explicitly) causal or consequential (the Strategic Focus hypothesis). In Experiment 2, we pseudo-randomly intermixed causal and consequential sentences and showed that Early effects still occurred on a trial-by-trial basis, immediately after the connective signaled the type of ending to the sentence – causal or consequential - ruling out a strategic explanation of the kind we considered (Strategic Focus). This information from the connective was combined with the causal or consequential bias of the main clause verb to determine preferential looks to the picture of the relevant NP.

In addition to Early Effects, we also looked for Late (end of sentence) Effects, and Very Early Effects, before the conjunction had been heard. The basic Late Effects favoring the cause in causal continuations and the consequence in consequential continuations were clear and as expected, though they are not relevant to our main hypotheses because all viable theories claim that verb bias and information about the conjunction (and the details of the explicit cause or consequence) will be used at the latest by the end of the sentence to compute the correct interpretation of the sentence. An informative finding in the Late Effect regions was that, in Experiment 2, we saw evidence of an overall favoring of causes over consequences, giving some limited support to the Causal Focus hypothesis for mental state verbs.

Very Early Effects, which relate more directly to the Causal Focus and Consequential Focus hypotheses, are of interest, for two reasons. First, based on empirical observations by Kehler et al. (2008), causes might be favored over consequences in eventualities involving mental states, even though in narratives, where sentences of the kind we presented are likely

to be encountered, there is a default tendency to move from events, but not necessarily states, to their consequences. Second, the previous literature has provided mixed evidence on whether such effects occur in on-line processing.

Our experiments provided no clear evidence for Very Early Effects. In both studies there was a numerical tendency for causes to be favored over consequences (Causal Focus), even though no causal continuations were used in Experiment 1. However, in that study the crucial effect of VBias, which hinted at an advantage for causes, was not significant, and in Experiment 2, where there was a mixture of causes and consequences, it was only marginally significant. Further work is needed to investigate whether such effects are robust and, if so, what is their nature. Is there, for example, a general tendency to favor causes, or is any such tendency restricted to states rather than events. Our only clear evidence for a favoring of causes over consequences came at the end of the sentences. It will be important to establish, in further work, whether this effect is robust, and whether it varies with the kind of verb studied, again in particular (mental) state verbs vs. event verbs.

In this context, another question that deserves further investigation is whether event verbs, to which Moens and Steedman's (1988) analysis does apply, might show Very Early preferences for consequences rather than causes, as suggested by the results of Grüter et al. (2018) for transfer verbs. However, investigating this issue more generally may prove problematic, because event verbs tend not to have such strong implicit causality and implicit consequentiality biases as the state verbs used in the current studies.

Conclusion

We have shown that implicit consequentiality information, like implicit causality information, can be deployed early in on-line processing. This information allows listeners to focus on implicit consequences before it becomes clear how those implicit consequences relate to explicitly presented consequences. Since the same verbs, at least in the Stimulus-

Experiencer and Experiencer-Stimulus classes of mental state verbs that we studied, have different implicit causes and consequences, the on-line focusing mechanisms that we have uncovered rely on a trial-by-trial basis on sensitivity to detailed aspects of verb semantics, and sentential context, in particular the occurrence of causal or consequential connectives. The effects of implicit consequentiality occur both when all sentences end with explicit consequences, and when causal and consequential sentences are mixed. Furthermore, effects of implicit causality are also found in the latter case, indicating that different types of information are rapidly deployed on a sentence-by-sentence basis. We have also provided evidence that causes are favored overall for these mental state verbs (in the Late Effects) and have pointed out that the same may not be true of event verbs, which, therefore, deserve further study. The kind of focusing that emerges in these studies should not necessarily be equated with forward inference making and, indeed, we have provided reasons why it should not be so equated. So, although our results are incompatible with the idea that implicit causality and implicit consequentiality information are only used at the point of integrating information in full clauses, they leave open the possibility that what we call inferencing only occurs at that point.

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Footnotes

¹We note that the term “implicit consequence” is not as felicitous when applied to the person associated with the consequence, rather than the consequent action or state, as the term “implicit cause” used in a similar way. We will, however, adopt the convention of referring to this person as the implicit consequence.

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³The binning procedure is provided by SR research for processing data from Visual World experiments. The parameters are designed to produce significant data reduction without losing track of when an eye movement occurred.

⁴In the difference score analysis, the intercept indicates whether there is an overall tendency to look at the NP1 or the NP2 pictures, and the Verb Bias main effect shows whether there are different tendencies to look at those pictures for NP1 biased and NP2 biased verbs.

⁵There are several types of case where the `dummy()` function from `lme4` has to be applied to factors in order to fit the correct model. See the discussion at <https://github.com/lme4/lme4/issues/182> for the case of random slopes without random intercepts. The `dummy()` function is also needed, as in this case, when including random effect interaction terms without the corresponding main effects. It is also needed when fitting zero correlation random effect models with the `||` operator.

Table 1

Proportion of looks to NP1 and NP2 pictures in the padding phrase before “and so” as a function of verb bias

		Looks To		
		Picture of NP1	Picture of NP2	
Consequentiality	NP1 Bias	.163	.385	.274
Bias	NP2 Bias	.208	.382	.295
		.186	.384	.285

Table 2

Proportion of looks to NP1 and NP2 pictures during and just after “and so” as a function of verb bias

		Looks To		
		Picture of NP1	Picture of NP2	
Consequentiality	NP1 Bias	.297	.256	.277
Bias	NP2 Bias	.263	.329	.296
		.280	.293	.286

Table 3

Proportion of looks to NP1 and NP2 pictures at the end of the period for which the pictures were on the screen as a function of verb bias

		Looks To		
		Picture of NP1	Picture of NP2	
Consequentiality	NP1 Bias	.382	.303	.342
Bias	NP2 Bias	.312	.398	.355
		.347	.350	.349

Table 4

Proportion of looks to NP1 and NP2 pictures during and just after “and so” or “because” as a function of verb bias and conjunction

Conjunction	Causal Bias	Looks To		
		Picture of NP1	Picture of NP2	
“because”	NP1 Bias	.316	.253	.284
	NP2 Bias	.283	.306	.294
“and so”	NP1 Bias	.287	.300	.294
	NP2 Bias	.315	.256	.286
		.300	.279	.217

Table 5

Proportion of looks to NP1 and NP2 pictures in the padding phrase before “and so” as a function of verb bias

		Looks To		
		Picture of NP1	Picture of NP2	
Causal Bias	NP1 Bias	.243	.328	.285
	NP2 Bias	.220	.344	.282
		.231	.336	.283

Table 6

Proportion of looks to NP1 and NP2 pictures at the end of the period for which the pictures were presented as a function of verb bias and conjunction

Conjunction	Causal Bias	Looks To		
		Picture of NP1	Picture of NP2	
“because”	NP1 Bias	.391	.287	.339
	NP2 Bias	.289	.409	.349
“and so”	NP1 Bias	.337	.372	.354
	NP2 Bias	.393	.298	.3
		.352	.341	.347

Figure Captions

Figure 1

Proportion of looks to each of the 4 pictures (NP1, NP2, PP, DIST) in 20msec bins for the 10 second period during which the images were on the screen in Experiment 1. Left-hand panel shows results for trials in which the verb had NP1 causal bias (NP2 consequential bias). Right-hand panel shows results for trials in which the verb had NP2 causal (NP1 consequential bias). Analysis of Late Effects was for the period between the two vertical black/solid lines at 6720msec and 10000msec. The blue line at 839msecs indicates the average start time for the playing of the audio file containing the sentence.

Figure 2

Proportion of looks to each of the 4 pictures (NP1, NP2, PP, DIST) in 20msec bins from 200ms before the start, in the audio file, of the padding phrase at the end of the first clause (“PP”) to 800msec after the start of the phrase. Timing was resynchronized to the start of the padding phrase on a trial-by-trial basis. Left-hand panel shows results for trials in which the verb had NP1 causal bias (NP2 consequential bias). Right-hand panel shows results for trials in which the verb had NP2 causal (NP1 consequential bias). Analysis of Very Early Effects was for the period between the two vertical black/solid lines at 200msec and 1500msec after the start of the padding phrase. The red line at 0msecs indicates the start of the padding phrase in the audio file containing the sentence.

Figure 3

Proportion of looks to each of the 4 pictures (NP1, NP2, PP, DIST) in 20msec bins from 200ms before the start, in the audio file, of the conjunction (“and so” or “because”) to 800msec after the start of the conjunction. Timing was resynchronized to the start of the

conjunction on a trial-by-trial basis. Left-hand panel shows results for trials in which the verb had NP1 causal bias (NP2 consequential bias). Right-hand panel shows results for trials in which the verb had NP2 causal (NP1 consequential bias). Analysis of Early Effects was for the period between the two vertical black/solid lines at 200msec and 1200msec after the start of the conjunction. The red line at 0msecs indicates the start of the conjunction in the audio file containing the sentence.

Figure 4

Proportion of looks to each of the 4 pictures (NP1, NP2, PP, DIST) in 20msec bins for the 10 second period during which the images were on the screen in Experiment 2, Top row shows results for trials in which the verb had NP1 causal bias (NP2 consequential bias). Bottom row shows results for trials in which the verb had NP2 causal (NP1 consequential bias). Left column shows results for sentences with the conjunction “and so”. Right column shows results for sentences with the conjunction “because”. Analysis of Late Effects was for the period between the two vertical black/solid lines at 6720msec and 10000msec. The blue line at 844msecs indicates the average start time for the playing of the audio file containing the sentence.

Figure 5

Proportion of looks to each of the 4 pictures (NP1, NP2, PP, DIST) in 20msec bins from 200ms before the start, in the audio file, of the padding phrase at the end of the first clause (“PP”) to 800msec after the start of the phrase. Timing was resynchronized to the start of the padding phrase on a trial-by-trial basis. Top row shows results for trials in which the verb had NP1 causal bias (NP2 consequential bias). Bottom row shows results for trials in which the verb had NP2 causal (NP1 consequential bias). Left column shows results for sentences with

the conjunction “and so”. Right column shows results for sentences with the conjunction “because”. Analysis of Very Early Effects was for the period between the two vertical black/solid lines at 200msec and 1400msec after the start of the padding phrase. The red line at 0msecs indicates the start of the padding phrase in the audio file containing the sentence.

Figure 6

Proportion of looks to each of the 4 pictures (NP1, NP2, PP, DIST) in 20msec bins from 200ms before the start, in the audio file, of the conjunction (“and so” or “because”) to 800msec after the start of the conjunction. Timing was resynchronized to the start of the conjunction on a trial-by-trial basis. Top row shows results for trials in which the verb had NP1 causal bias (NP2 consequential bias). Bottom row shows results for trials in which the verb had NP2 causal (NP1 consequential bias). Left column shows results for sentences with the conjunction “and so”. Right column shows results for sentences with the conjunction “because”. Analysis of Early Effects was for the period between the two vertical black/solid lines at 200msec and 1100msec after the start of the conjunction. The red line at 0msecs indicates the start of the conjunction in the audio file containing the sentence.

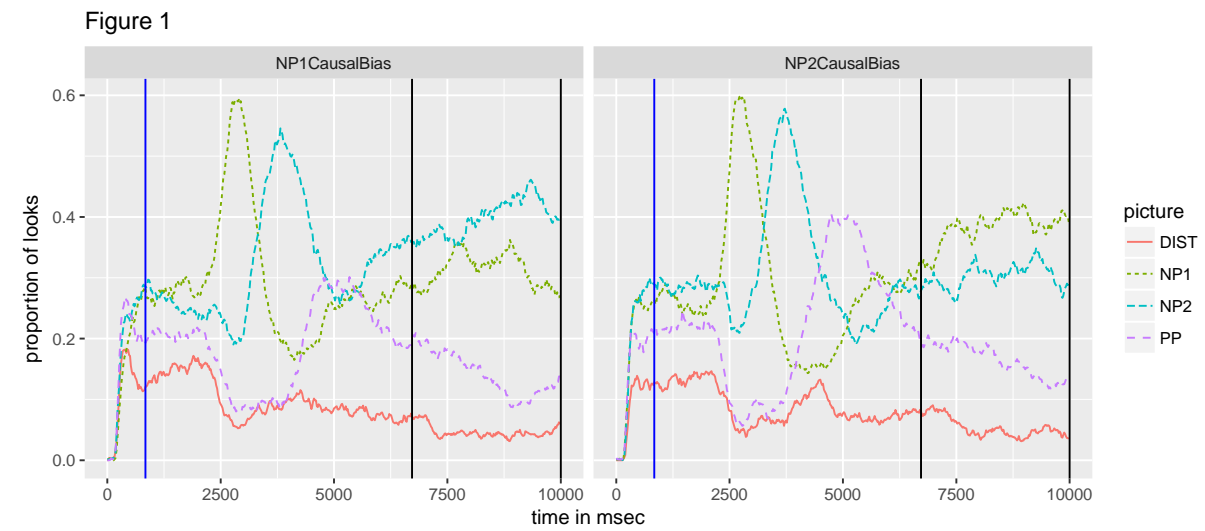


Figure 2

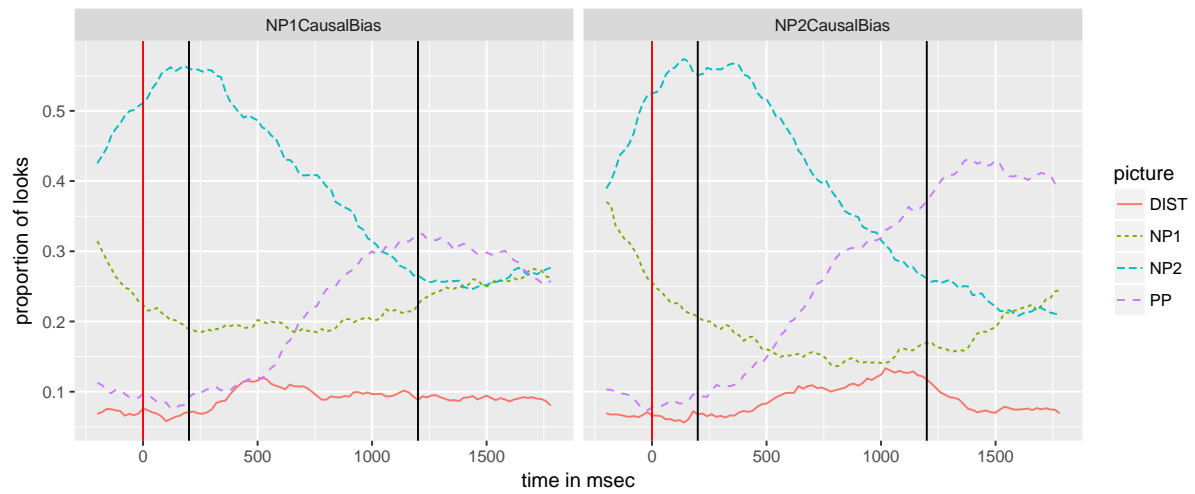


Figure 3

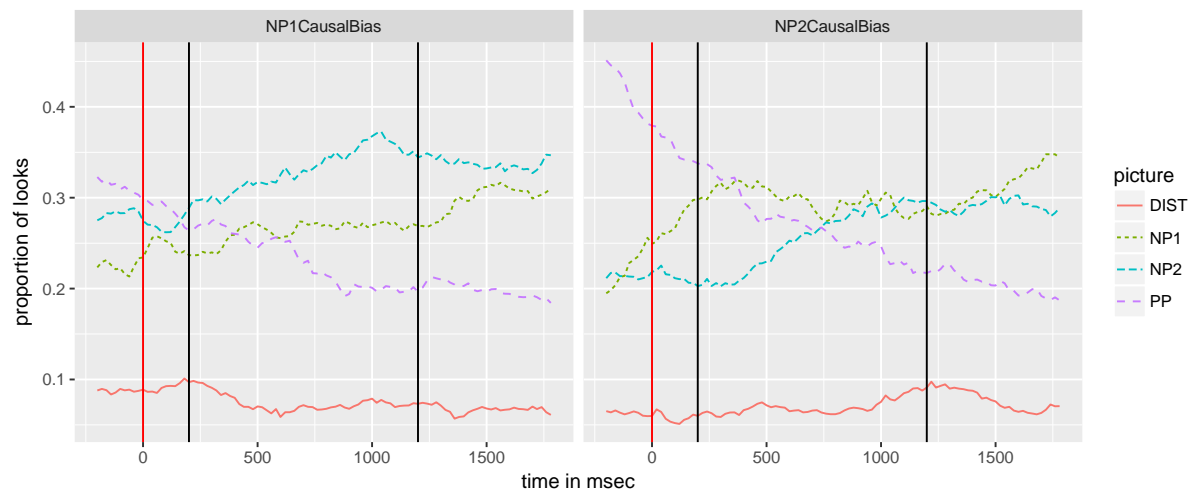


Figure 4

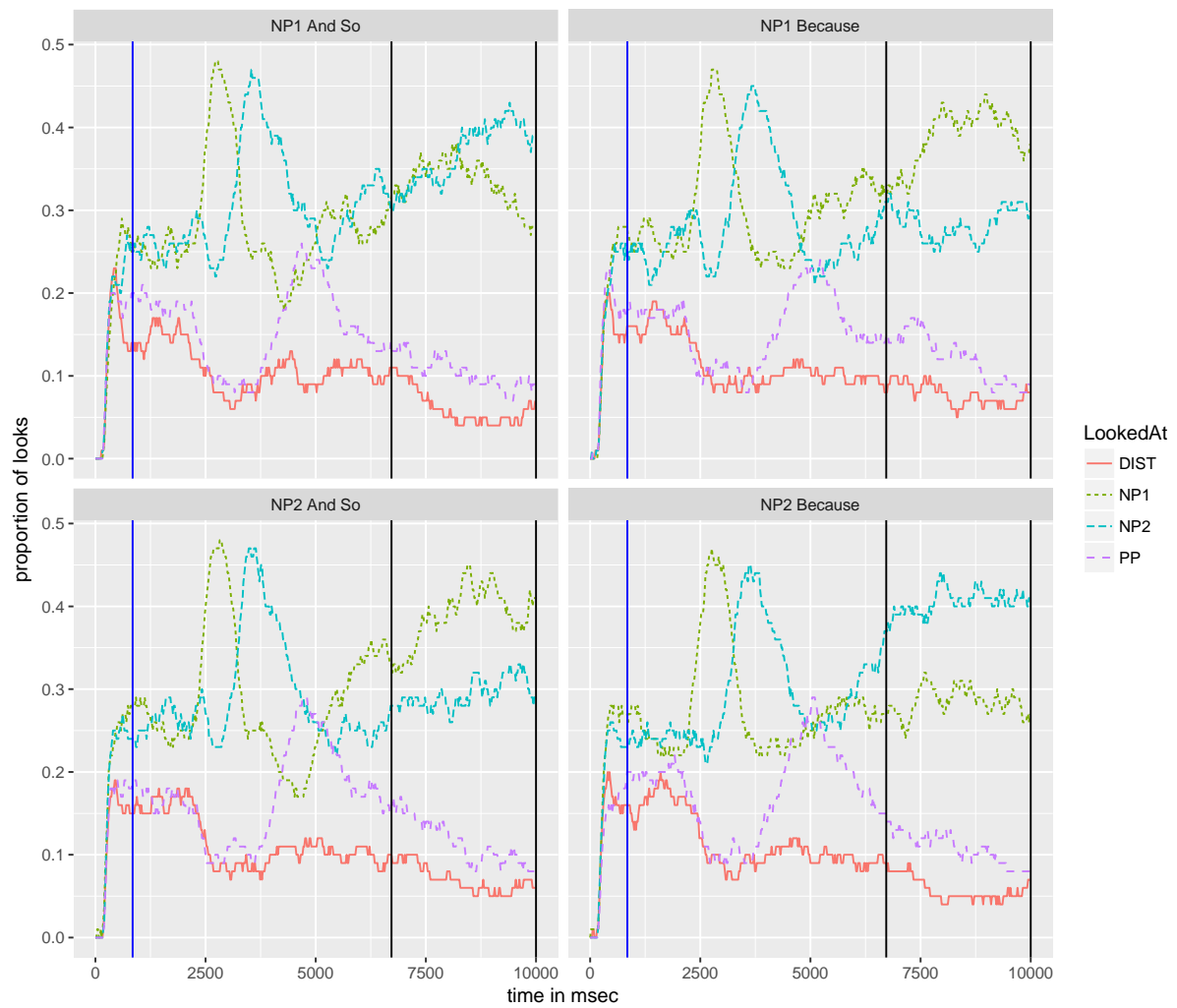


Figure 5

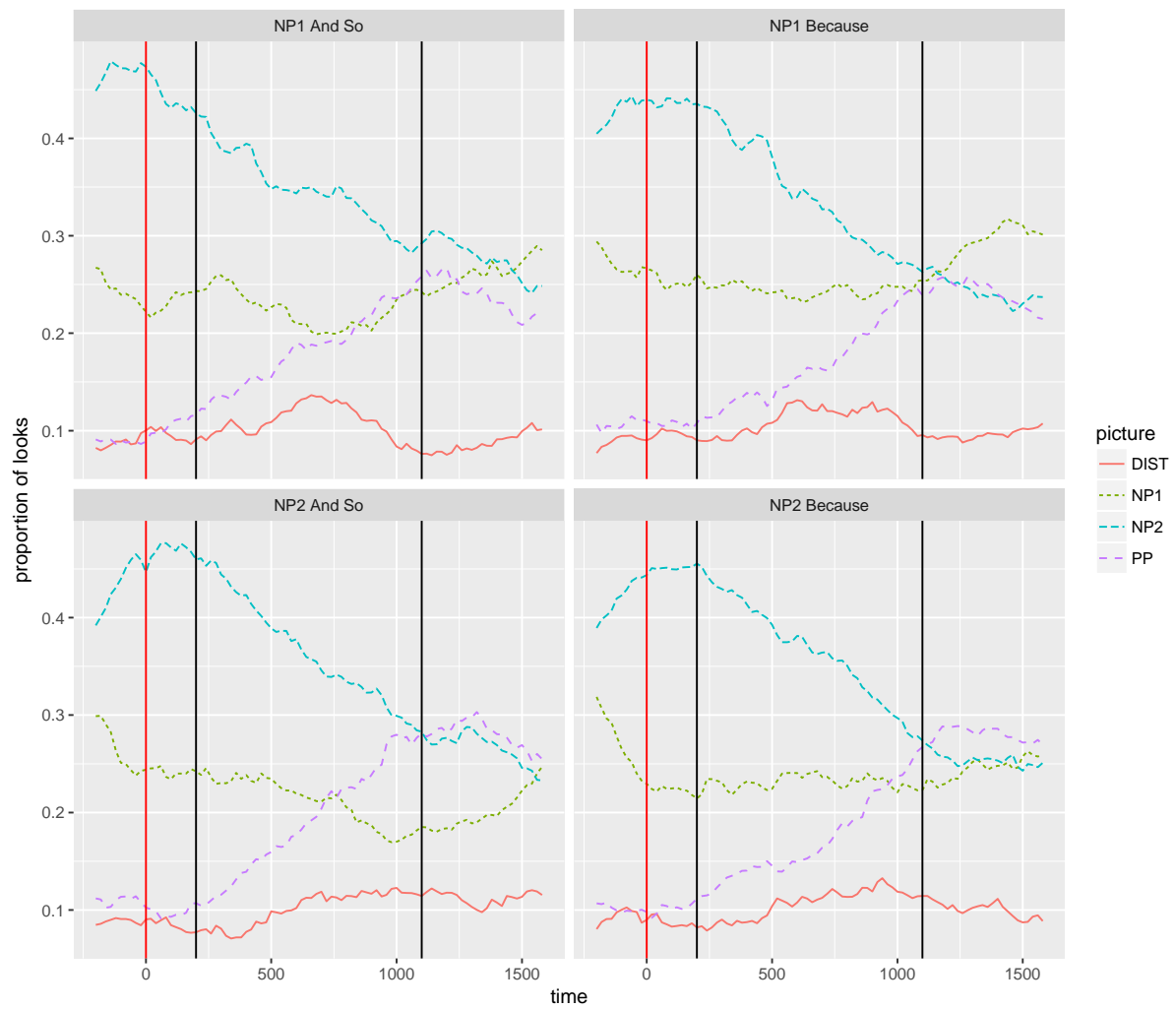


Figure 6

